National Aeronautics and Space Administration

Technology, Innovation, & Engineering Committee
of the
NASA Advisory Council

Jet Propulsion Lab (JPL)
Pasadena, California
July 27-28, 2015

Meeting Minutes

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G. Michael Green, Executive Secretary **William F. Ballhaus, Jr., Chair**

NASA Advisory Council
Technology, Innovation, and Engineering Committee
Jet Propulsion Lab
Pasadena, California
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Meeting Minutes

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Welcome and Overview of Agenda/Logistics
Mr. G. Michael Green, Executive Secretary of the NASA Advisory Council (NAC) Technology, Innovation, and Engineering (TI&E) Committee, opened the meeting with a review of the agenda, which included a joint meeting with the Human Exploration and Operations (HEO) Committee.

Opening Remarks and Thoughts
Dr. William Ballhaus, TI&E Chair, welcomed the Committee members. He noted that the agenda would address an issue that remained from the last NAC meeting: that until NASA invests in space technology at a level sufficient to drive down risk, the Agency will keep slipping on its goals. Dr. Ballhaus asked the Committee to discuss and possibly revise its Finding from the previous meeting.

Space Technology Mission Directorate Status and Update
Mr. Stephen Jurczyk, Associate Administrator of NASA's Space Technology Mission Directorate (STMD), began his presentation by noting that one of the challenges facing STMD has been the competing priorities of the President and Congress. He has tried to emphasize that STMD enables space exploration, science, and more robust commercial space enterprise.

Budget
The House of Representatives has marked up an STMD budget of $625 million, which is essentially flat. Of this, $600 million is for ongoing work and $25 million is for the Jupiter Icy Moons technology. There was also direction to spend $20 million on nuclear propulsion. The Senate's preliminary funding included $20 million for a flight opportunities program to develop a small launch vehicle capability. This is something that STMD has been looking at for a while and for which the Directorate has released two solicitations. The Senate bill also includes direction to fund satellite servicing, at $150 million. This would be mostly procurement dollars and come from the total Senate mark-up of $600 million. The $150 million could not come from anywhere else. Yet at the same time, STMD must allot about $200 million to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

Dr. Mary Ellen Weber pointed out that the $150 million directed toward satellite servicing was essentially a cut. She thought that NASA's response to the cut was passive; this was an emergency, and it did not come across that way. She was concerned about NASA's internal communications and whether others understand what these cuts mean to STMD.

Mr. Jurczyk discussed, as another fixed cost, the approximately $100 million that goes to civil servants. So the $150 million cut is about 65 percent of the discretionary spending. That would force STMD to stop much of its work and shift much of the procurement funding to what civil servants can do, and severely limit some of the student programs. Dr. James

Reuther, STMD Deputy AA for Programs, added that this would cause STMD to cancel many significant projects, such as the coronagraph for the Astrophysics Division's (APD) Wide Field InfraRed Space Telescope (WFIRST). None of that would be able to continue; the program would have to be reconstituted from scratch. Dr. Ballhaus said that this will require that Congress get the message on how this affects the efforts to go to Mars and other NASA projects.

Dr. Weber said that she was extremely concerned that the NASA Administrator's response mentioned none of this. Mr. Jurczyk said that STMD was working with Congress and within the Agency. Satellite servicing has been within the Human Exploration and Operations Mission Directorate (HEOMD) up until now. He will communicate the impact and how STMD would like to move forward. Dr. Weber said that she felt like the first response made STMD seem as if it is not a NASA priority.

Mr. Jurczyk said that STMD is developing a strategic implementation plan, and the space technology investment plan cuts across the Agency. These will help shape messages and communicate with stakeholders, while backing up funding decisions. The draft would be available soon, and he wanted TI&E feedback.

There have been organizational changes in STMD. Most prominently, Dr. Reuther is leaving the Agency for the private sector; Mr. James Reuter from the Marshall Space Flight Center (MSFC) will fill the role while working on a one -year detail.

Dr. Ballhaus asked if it might be possible to push the technology demonstrations into the other mission directorates. Mr. Jurczyk said that it depends on the technology, its application, and where it is in the process. There are two solicitations out. One is a tipping point effort that takes Technology Readiness Level (TRL) 5 products to TRL6 or more. This requires a 25 percent minimum investment from industry. The second, the Agency Collaboration Opportunities (ACOs), would be non-reimbursable Space Act opportunities allowing industry to leverage the capabilities of the NASA centers. NASA will fund the center expenses but not the industry part. Dr. Reuther said that these give industry a great opportunity to see what NASA can do, while identifying industry interests for NASA. This is part of what NASA is doing for commercial space.

Mr. Jurczyk said that STMD has created an early stage portfolio and is creating a commercial partnerships portfolio that includes SBIR/STTR and the Centennial Challenges. There also continues to be a university engagement effort.

Joint HEO and TI&E Meeting Call to Order

Mr. Green opened the joint HEO and TI&E meeting with a quick review of the agenda.

Overview of Space Technology

Mr. Jurczyk discussed collaboration with HEOMD and some of the technologies that STMD is developing. STMD is the cross-cutting space technology program for the Agency, enabling affordable and reliable systems capabilities for stakeholders. The systems-driven approach helps create balance and responsiveness. STMD works across the TRLs using technology push and pull, leveraging partnerships, and relying on a combination of competitions and directed efforts to meet NASA needs. STMD infuses rapidly or terminates promptly. When working with other Federal agencies, STMD often receives funding from those agencies in order to conduct the work.

Many of the technologies in which STMD invests are meant to enable space exploration and future NASA missions to Mars and beyond. Among the examples Mr. Jurczyk gave were

solar electric propulsion (SEP) and entry, descent, and landing (EDL) technologies like the Low-Density Supersonic Decelerator (LDSD). These will enable Mars exploration. STMD is developing a strategic implementation plan across eight strategic investment areas. Programs include transformative technology breakthroughs such as game-changing development; pioneering concepts such as space technology research grants; and creating markets through such activities as SBIR/STTR.

The majority of the current budget goes to mid-TRL projects, technology demonstrations, and SBIR/STTR. SBIR/STTR has grown, and it is a challenge to find the funds for other programs as a result. This year, the Senate has directed $150 million to satellite servicing. If that funding scheme becomes an actuality, STMD would have to reformulate.

STMD shares some objectives with HEOMD's Advanced Exploration Systems (AES) program. Both are developing technologies that are being transitioned into missions. Mr. Jurczyk gave examples of STMD/AES collaboration in such areas as Mars EDL instrumentation and nuclear systems. In advancing future capabilities for the SLS and Orion launch vehicles, STMD has supported work on such elements as composite cryogenic propellant tanks and SEP. STMD has also worked with commercial entities like SpaceX and the aerospace industry.

The Mars Science Lab (MSL) relied on STMD for its innovative comprehensive EDL measurements on the flight through the Martian atmosphere in 2012. STMD has offered the Science Mission Directorate (SMD) the opportunity to have investigators work on demonstrations in eight areas. STMD has also partnered with universities through competitive solicitations.

Discussion
Dr. Stephen Condon of the HEO Committee said that programs often need technologies by certain dates, which can be difficult to do. At the same time, some technologists are reluctant to conclude testing, and some program managers are risk averse and slow to accept new technologies. Mr. Jurczyk agreed that these issues arise at NASA. STMD tries to address the situation by having HEOMD and SMD engaged in STMD planning. This facilitates understanding of mission application needs, allows STMD to plan more effectively, and makes HEOMD more comfortable with STMD taking things forward through a structured approach to infusion.

Scientists in particular have a bias for what has already flown, so STMD offered technology demonstrations off the critical path to enable their work. Dr. Reuther added that STMD often brokers arrangements that require the mission directorates to commit to successful actions so that STMD is not just spending money. That has worked increasingly well as the mission directorates have gained confidence in STMD's work. He gave the example of the coronagraph for WFIRST, which now has an "on-ramp" date.

Mr. James Odom of the HEO Committee asked what Mr. Jurczyk was most proud of from STMD. Mr. Jurczyk mentioned the large composite cryotank, SEP, and magnetic shielding technology. Dr. James Voss of the HEO Committee asked how STMD determines priorities in the face of limited resources. Mr. Jurczyk said that the Agency's roadmaps cover the range of what could be done, and those are distilled into cross-cutting programs for the STMD strategic investment plan. There are also nine principal technologists across the eight STMD areas to make these decisions. The process is becoming better defined over time.

Evolvable Mars Strategy – HEO Technology Development Efforts
Mr. Jason Crusan, Director of AES, discussed technology development from his program's perspective. The Evolvable Mars Campaign (EMC) is an ongoing series of analyses to define

the capabilities and elements needed for a sustainable human presence on Mars. It represents a design philosophy shift and relies upon Design Reference Missions (DRMs) as inputs. The project has done a lot of work on surface exploration, staging work, SEP, and other elements.

Mr. Crusan reviewed the EMC FY16 plans in areas such as transportation and habitation, and noted major results. Commonality of systems allows decisions to be made later. Examples of areas of commonality include SEP, habitation, and the transportation of crew and cargo to and from deep space. For example, there could be a modular approach to habitation, with habitats parked for reuse, growing out of EMC.

Earth-reliant near-term objectives are tied to proving ground objectives. To enable human missions to Mars, NASA will need to validate and demonstrate much of this. The NASA technology roadmaps and investment plan guide these investments. EMC also engages with the commercial sector in areas such as commercial resupply and crew, the Asteroid Redirect Mission (ARM), and more.

Mr. Crusan went into greater detail on the crew mobility system, which is now testing a fully integrated next generation space suit and portable life support systems, and the deep space habitation systems domains, such as radiation protection work and spacecraft fire safety. The Bigelow Expandable activity model was initiated in January 2013 and is already available for launch, serving as an example of the EMC acquisition model. Another successful campaign was the Morpheus rapid prototype lander, which employed an innovative process and supported workforce development. EMC has been doing autonomous mission operations and core flight software, among other operations activities.

EMC has used public challenges, like crowdsourcing, for software coding. Strategic knowledge gap (SKG) development is ongoing and jointly sponsored by HEOMD and SMD. SKGs inform planning and design, as well as near-term investments. The Mars 2020 mission will address SKGs for human exploration. Through Broad Agency Announcements (BAAs), the program has solicited three critical areas for technology maturation: advance propulsion systems, habitation systems, and small satellite systems. Private sector partners must have a track record on this and pay at least 50 percent of the costs. Some of the BAA partners have proprietary products and systems, but they are investing. In the area of habitation, for example, both NASA and business have interests. Cost-sharing is an off-set.

Hydrocarbon Engine Overview

Mr. William Hill, the HEOMD Deputy Associate Administrator for Exploration Systems Development (ESD) and Mr. James Norman, Director of Launch Services for HEOMD, presented a discussion on hydrocarbon engines and launch services. Mr. Norman explained that HEOMD has worked with the Air Force on engine and launch systems. NASA is completing its lox/hydrocarbon studies, having spent close to $50 million on this and related work. The FY15 funding helps support a joint development test with the Air Force.

Mr. Hill explained the incremental path to lift capabilities, which led to the determination that the exploration upper stage provides the needed abilities. The Agency decided in 2014 not to spend more on hydrocarbon engines, though some activities were completed. NASA and the Air Force have a reciprocal agreement to provide certain capabilities to each other. NASA has offered its facilities and expertise to both the Air Force and industry. From FY16 on, however, the Air Force provides the funding. There are also unfunded Space Act Agreements between MSFC and industry.

Dr. Ballhaus raised the issue of language limiting the ULA launches. The Air Force would like to have high demonstrated reliability, and SpaceX is still working on that. This is complicated by a growing access-to-space issue, which NASA has some ability to address, though this is mostly an Air Force problem. Mr. Norman said that there is a prohibition on using Russian engines on national security launches, though it does not go into effect until FY17. ULA is pursuing alternatives to the engine. Dr. Ballhaus observed that a methane engine would need to have its rocket redesigned, which will not happen by 2017 or even 2022. Mr. Kenneth Bowersox, HEO Committee Chair, said that if the Air Force were to back away from the Atlas 5 infrastructure support, it could affect NASA costs on crew launches. Mr. Norman said that that is the worst-case scenario.

NASA Launch Services Overview

Mr. Darren Bedell explained that the Launch Services Program (LSP) buys commercially available launch services and provides advisory services with a highly experienced workforce. Dr. Ballhaus noted that the initial failure rates have been high for the new vehicles introduced by commercial entities, whereas the government has been more successful, possibly because there has been sharing of history and lessons learned across the different programs. Industry does not do that. If the commercial sector failures continue, they might want to look at that process and how to share.

Mr. Bedell agreed, noting that since 1990, it was almost a given that there would be a failure within the first six launches of a new vehicle. That seems to be changing, however. Failures tend to resolve themselves by the tenth launch. However, some companies discontinue their efforts, especially if they have two failures. The government mission assurance practices make a difference.

Mr. Bedell reviewed LSP's current and future fleets in terms of certification, which is to NASA's standards. There are no financial health restrictions except in the emerging class of launch vehicles. Nor must launches take place from a particular location. The launch director has authority to cancel up to the day before a scheduled launch. NASA has a voice in deciding whether ISS is ready to receive cargo, but ISS makes the final decision. It is a safety issue.

Mr. Bedell presented a project timeline and described the LSP acquisition strategy, which covers a range of risk tolerances. The LSP strategy in helping companies get started begins with a low-risk contract for something like education-based cubesats. From there, NASA helps them grow. These "starter contracts" are tailored and flexible. NASA is accountable for its choices across a range of risk postures. For example, on the James Webb Space Telescope (JWST), NASA decided to go with a very credible foreign supplier, as this is a highly visible mission. NASA is 100 percent accountable for mission success and has a clear vote on the readiness of the launch vehicle.

Dr. Ballhaus said that NASA had a series of mission failures in the mid-1990s, and the failure review found that no one knew what they were responsible for from an insight standpoint. Mr. Bedell said that in 1998, as the failure lessons were coming out, LSP established criteria for insight. LSP seeks a reason to launch and verification that the rocket is good; there are criteria for that in the guidance. The launch decision process brings out all of these items. There have been two failures, which the investigation indicated were not due to accountability. The Program constantly looks at what can be done better.

Mr. Bedell described the LSP technology disciplines and discussed certification requirements. The Program looks at the vehicles and asks if there is a way to do things better, rather than using a launch readiness matrix like the Air Force does. LSP is more flexible and more

specific. Accountability exists through the engineering review process and technical authorities. Everything of significance that is documented requires a minimum of three signatures. The chief engineer for the program sees everything, and the big items are brought through the system for all to see. Dr. Ballhaus expressed concern that there was no individual accountability, saying that if everyone is accountable, no one is. Mr. Bedell said that LSP prefers to think in terms of responsibility. If something goes wrong, the Program does not try to identify and remove an individual. The team feels very deeply that they must do their jobs. They have been a team for 17 years, and that sense of being part of the team brings a huge sense of accountability. They have all stayed late at night wondering how they could make things better.

Dr. Ballhaus maintained that individual accountability is a key. Mr. Norman said that he agreed, and explained that in LSP, the first line of defense is the inculcation of responsibility. The only rocket the government is currently overseeing is SLS. So NASA must make sure that industry understands accountability as well. It is a partnership, a relationship. Mr. Bedell added that there is direct traceability to everything LSP does.

LSP has an advisory role in commercial resupply services (CRS). The guiding principle is that the commercial provider, not NASA, will be responsible for the launch success of the service. For the commercial crew program (CCP), there is an understanding with ISS of the LSP role. LSP provides engineering expertise in helping ISS run its process; Mr. Bedell described how that worked.

Joint Committee Discussions and Recommendations

Mr. James Oschmann said that he was hoping to learn where the two committees could work better together to achieve improvements. There are huge budget pressures and political problems. Dr. Ballhaus said that it seemed they were on the flexible path approach with no mission driving the efforts. He felt there were a lot of ideas but little focus. Mr. Oschmann agreed that the technology portfolio had a lot of push, but there must be some pull. It is hard to make a funding case to the public and politicians without having a focus. He worries that if they wait too long for the big picture, it will be difficult to create excitement in terms of funding.

Ms. Nancy Ann Budden of the HEO Committee noted that there is also time criticality on developing the technologies; some are needed sooner than others. The blending of critical technologies with budget realities results in fewer technologies to focus on sooner. Mr. Bowersox said that this is part of the EMC charge, to zero in on what should be the emphasis.

Dr. Ballhaus asked how to best frame an urgency argument. Perhaps the Associate Administrators could address this. Mr. Jurczyk said that there must be a long-term goal and knowledge of when the various products are needed in order to work back to develop the timeframes. Mr. Gregory Williams, Deputy Associate Administrator of HEOMD, agreed that this could be done as a top level guide. Mr. Oschmann suggested that emphasizing the cross-cutting items from a big picture mission that focuses on the roadmaps from the two mission directorates could produce a good picture. However, the story does not seem to be coming across.

Dr. Weber said that she was not sure that the HEO Committee appreciated what the Senate was trying to do to STMD. Taking a total budget of $600 million, with $200 million allotted to SBIR/STTR and much of the rest allocated to civil servants, means that the $150 million in directed spending is 70 percent of the money available to do any of these programs they had discussed at the joint meeting. This new proposal will cripple what STMD can do. She

was not sure that a recommendation could come out of that, but she wanted the HEO Committee to be aware of this dire situation facing STMD. She did not think that talk about collaborating and going forward was relevant if STMD took this cut. Mr. Oschmann agreed, noting that there would be nothing new in STMD, only management of the current programs. Mr. Jurczyk added that STMD would have to reformulate the program completely. Most of the other work would cease. Dr. Weber pointed out that, in context of the two directorates working better together, this change would make the STMD contribution virtually nil.

Dr. Reuther said that every organization, whether industry or government, needs to do advanced capabilities and devote a portion of its plan R&D. NASA devotes less than 5 percent to it, which is not necessarily sustainable. NASA has a history of doing things to embolden and lead the aerospace community, but it cannot do that with so little R&D.

Mr. Bowersox advised three draft findings for discussion. First, the organizations are working together well. Second, the roadmaps support exploration efforts and critical technologies. Third, delaying implementation of the roadmap delays exploration. Dr. Ballhaus advised accepting these three items. If they make the case that certain things are needed in order to accomplish the public belief that humans will someday go to Mars, perhaps they could get more funding. Dr. Weber was concerned that even that runs the risk of falling on deaf ears, because there was nothing actionable. Some in Congress are saying that this is not a priority. While the advisory committees were chartered to advise the NASA Administrator, she remained dismayed that there had been no pushback from him when he spoke out against other cuts. He should know that the committees are very concerned.

Mr. Bowersox suggested stating that if NASA does not execute the technology program, it will delay efforts to go further, and if it cannot do SEP development, it cannot do a mission to Mars. Dr. Ballhaus and Mr. Bowersox said that they would develop the findings, and Ms. Budden and Mr. Oschmann agreed to help.

Dr. Ballhaus noted that the committees would need to pay continued attention to engine development, and the HEO Committee may need to watch LSP. The assurance process is critical, as accountability will be a challenge. Mr. Bowersox added that if the Air Force does not get the RD-180 missions, that could affect NASA. There is also commercial crew mission assurance, which could be affected by launch vehicle expense. It would be reasonable to have a discussion in the future to ask for an update.

Adjournment

The meeting was adjourned at 5:49 p.m.

July 28

Welcome and Overview of Agenda/Logistics
Mr. Green opened the second day of the meeting by welcoming the Committee members.

Opening Remarks and Thoughts
Dr. Ballhaus introduced the first speaker, Dr. Charles Elachi, Director of NASA's Jet Propulsion Lab (JPL).

Welcoming Remarks
Dr. Elachi welcomed the Committee members to JPL and gave a brief history of the facility. Currently, CalTech has 5,300 employees at JPL; they are focused primarily on robotics and astrophysics. Dr. Elachi gave some examples of JPL work that has made a difference for NASA, including the Mars rovers. JPL is now demonstrating an STMD helicopter that can be flown on Mars 2020, about the size of a small drone. This will enable greater Mars exploration. JPL is also developing coronagraph technology that will help identify and analyze planets found via astrophysics missions.

Dr. Ballhaus asked Dr. Elachi for his advice on getting across the message about the need for technology demonstrations. Dr. Elachi said that STMD needs a passionate champion. The Directorate needs to identify important people in Congress who are passionate about particular NASA projects and make them see that STMD activities must happen first. If STMD can show them that their favorites require STMD technology development, they will help. That changes the language in bills. When members of Congress start marking a bill, they take priorities from each member on the Appropriation Committee. JPL is working with Mr. Jurczyk on how to articulate this.

Mr. Gordon Eichhorst asked about JPL's treatment of intellectual property. Dr. Elachi explained that CalTech has been proactive on intellectual property and strongly encourages it. From any JPL license, one third of the royalties go to the employee and the rest to CalTech, which then puts much of that into the employee's lab.

After Dr. Elachi left, Dr. Ballhaus asked Mr. Jurczyk for an update on the urgency argument. Mr. Jurczyk replied that that is his focus. Technology development enables the missions of the future. Congress needs to see the connections between a Europa mission and technology development through STMD, for example. These activities take a long time and NASA needs to work on them now to enable future exploration. He lays out the story starting with the mission, then lays out the technologies needed. At times, the investment strategy has been ad hoc, and sometimes it is nonexistent. STMD has a more strategic approach that gives the lead time. Dr. Ballhaus said that if Mr. Jurczyk can show Congress the investments associated with the technologies that are needed for missions, he can show them the impact of cuts.

Update: Impacts on Past Budget Reductions on STMD Technologies
Dr. Reuther discussed the consequences of not being fully funded, a Committee focus for the past two meetings. His first response was not specific enough, so he was presenting the next cut, covering actual technologies that have been affected by the lack of full funding.

First was SEP. It is an essential capability for a human Mars mission and has multiple other cross-cutting applications into communications satellites, science and exploration, satellite

servicing and refueling, and many other activities. The "elevator" message is that the country needs SEP in order to get humans on Mars, so every slippage delays that. All of the SEP demonstration components are important in their own right. Dr. Ballhaus said that this needed to be simple, stating that this is path to human exploration of Mars and a critical step is the technology demonstration. That is the key, and STMD does not have the funding.

Dr. Reuther showed the demonstration mission concept, noting that NASA cannot get a stable launch date for planning because ARM is not fully funded and SEP is locked into that. It is a day-for-day slip for both. A SEP demonstration would cost $433 million, which significantly exceeds the STMD in-guide budget of $229 million. This gap has existed for 3 years and the ARM launch date keeps slipping.

Mr. Jurczyk added that this is the profile STMD has been forced to anticipate in its funding. Dr. Reuther said that when the Office of the Chief Technologist (OCT) was first formulated and STMD was created, the SEP demonstration was made a Directorate responsibility. That was 2011 and it has been in STMD plans ever since. NASA has lost a lot of time.

Dr. Weber said that if she were a member of Congress who did not care about ARM and did not know what SEP is, she would be hearing that a mission she does not care about is delayed and a technology she does not understand is delayed. STMD should say that the Mars mission needs SEP, SEP needs a demonstration, and a demonstration is not possible. Instead, Dr. Reuther's presentation showed how SEP ties to many things.

Dr. Reuther said that he would not take this same presentation to Congress. HEOMD gave the top two priorities as SEP and the solar array. The latter is a great story, however, as it was funded. NASA is now looking at doing a demonstration on ISS. The commercial satellite providers are already offering those arrays as part of their satellite systems for the future. The technology has been infused already, and with success.

Dr. Ballhaus said that STMD has done great work with this and might get a response that it has had a positive impact on industry, but it is not associated with a mission. Dr. Reuther replied that that was the strategy, and it relates to ARM. STMD does not care what the mission is as long as it can do the demonstration. ARM had a great timeline when first conceived, but it has not been funded because it is seen as not necessary. That inhibits STMD's ability to demonstrate SEP.

Mr. David Neyland asked if there were a way to work with the Senate directive to accelerate SEP. Dr. Reuther said that STMD cannot recast that earmark, and Mr. Jurczyk added that Congress disapproves of this kind of action. Mr. Oschmann was concerned about diluting the STMD message. He urged them to develop a single chart without the details. Mr. Michael Johns agreed, noting that STMD runs the risk of having more earmarks in the future if the message does not get out.

Dr. Reuther went on to describe other technologies that STMD has supported, such as laser communications, which is critical for science missions and human exploration of Mars, among other applications. STMD has had to descope this project repeatedly due to funding, and that has increased the total costs. The cost inflation is a direct result of not getting the planned budget. Other technologies in similar situations include integrated photonics and Cryogenic Propellant Storage and Transfer (CPST). There are many other examples that show that the technology costs grow due to delays and rephasing.

Mr. Oschmann observed that the presentation emphasized Mars and human exploration, but there was a similar situation regarding APD and coronagraph development. Mr. Jurczyk

added that WFIRST is a high priority in the current APD DS. Dr. Reuther agreed, noting that SMD stories are similar to those of human exploration of Mars. STMD is ramping up coronagraph funding, but diminished funding could have a negative effect on the Directorate's commitment to APD. A shortchange in funds could be devastating to SMD.

Dr. Ballhaus asked Dr. Reuther to do a single chart that has the key message on human exploration and science, the most important things that are not going to be done, and the consequences. He wanted something similar to an elevator speech. Dr. Reuther said that he would do separate charts for HEOMD and SMD. Dr. Weber reiterated Dr. Elachi's point about finding the right person in Congress. She suggested tailoring the message with the one-pager to get true champions. They do not care about all the other projects. Dr. Reuther said that the bigger challenge is finding the advocate.

Update on Deep Space Optical Communications (DSOC) Project

Mr. Thomas Glavich, Project Manager for DSOC at JPL, explained that this project is transitioning from technology development to flight readiness. DSOC is part of the Discovery 2014 Announcement of Opportunity (AO) and is on a path to be at TRL 6 to support the Discovery 14 payloads. Mr. Glavich explained the elements within the project, the limitations and communication scenario, and the components and basic specifications for the flight laser transmitter and the ground systems. He also described the technology maturation flow and hardware details.

One of the challenges that Mr. Glavich discussed throughout the presentation was vibration mitigation. There are specific technologies being developed to isolate and prevent vibration. Another issue is the uplink and downlink. The receiver is on the ground, and there are eye safety issues related to the downlink. These safety issues are significant and the team spends a lot of time thinking about them.

They are now waiting for the Discovery selections in order to begin discussions as a function of leading to TRL 6. The team is ensuring that the flight and ground systems remain as closely coupled as possible. This will function as a technology demonstration for Discovery; it will add more value to the science, and several proposers wanted to do exactly that.

Dr. Ballhaus noted that there are many new technologies on the flagship missions, while there are fewer on the small missions, which seems backwards. The TI&E recommendation on this was not accepted by the full Advisory Council, but it remains that properly managed technology infusion is reasonable for that class of missions. SMD said that it would incentivize some technology introduction. Mr. Jurczyk explained that flagship missions are not cost-capped, but the Discovery and AO missions are. This is an approach to leverage those missions by not putting the technology on the critical path and breaking the cost cap. If the demonstrations succeed, then the move will be to less risk aversion. This model affords a low-cost and efficient demonstration opportunity.

Dr. Ballhaus said that when a program is capped, often there is also a launch window that creates a schedule cap, and the only relief valve is risk. Mr. Oschmann pointed out that the science requirements are not cast in stone on these missions. Mr. Jurczyk agreed, but noted that there is a minimal set for a viable mission. Dr. Reuther added that reserves are held against key projects. There must be a willingness to pull some projects, or descope or delay them if they overrun. Mr. Oschmann noted that some of the emphasis on the cost caps was reaction to flagship overruns; the cost caps were set up to create a balance in the portfolio by having lower-cost missions. Mr. Jurczyck explained that SMD budgets its projects to get to the 50 percent confidence with the cost cap, then holds reserves to get to 70 percent.

Update on Deep Space Atomic Clock (DSAC) Project

Mr. Allen Farrington, DSAC Project Manager at JPL, and Dr. Todd Ely, the Principal Investigator (PI) for the project, discussed the latest developments. The fundamental enabling technology on GPS is the atomic clock, and one of the goals is to use it for other applications. Dr. Ely described the DSAC technology demonstration, the core physics, and the components. The team is taking it to TRL 7 and will help develop the next steps to usability after that.

DSAC will be a secondary hosted payload on the Surrey mission. The project will not compare DSAC to GPS directly, but will compare the datasets to validate DSAC. The project offers broad benefits for enhanced exploration. Current space clocks have a high error rate. DSAC will enable one-way tracking, which provides more communications that are also more precise. It would enable pinpoint landing on Mars and has a number of applications for the Europa mission. Dr. Ely described the payload and the initial results. This technology is cross-cutting and promotes the future of NASA navigation. It will launch in September 2016. An efficient spacecraft with DSAC will enable flexibility and get more with less, while also enabling other payloads to take advantage of pointing.

Update on Low Density Supersonic Decelerator (LDSD) Project

Drs. Mark Adler and Ian Clark, LDSD Project Manager and PI respectively, provided an update on what had happened with the project since Dr. Clark's presentation to TI&E in 2014. This technology is aimed at landing larger objects on Mars. Dr. Adler described the EDL technology state of the art, noting that NASA has not advanced qualification for parachutes for Mars since 1972.

Dr. Clark explained that the team is developing three main supersonic decelerators, which involves developing a large supersonic parachute, about the length of a Boeing 747. As there is no wind tunnel large enough to test the largest parachutes, the team had to devise new testing and therefore used a helicopter that links to a high-speed sled. Dr. Clark described the results of the testing. There was a failure in each case; in one case, it was due to the pull exceeding the test parameters. In another case, the parachute inflated, but then the Kevlar failed. The team must analyze what happened, as they now know that the paradigm from the past is not sufficient for understanding supersonic behavior. The failure provides more information than a successful test would have. The team is looking at three hypotheses and is back to the drawing board on the design and testing of these devices.

Dr. Adler added that the success thus far on Mars has been with parachutes carrying far less weight than their flight limit load. The LDSD tests went beyond those loads. Dr. Weber pointed out that the sport parachute industry is moving away from Kevlar and nylon. She and Dr. Clark discussed manufacturers, and she advised him to contact some of them, which he agreed to do.

Dr. Clark explained that the computational simulations the team has tried have been unsuccessful, as the parachutes are difficult to model. Mr. Jurczyk added that they are leveraging the work done elsewhere, but wake modeling is difficult. A long-term modeling effort at NASA's Ames Research Center (ARC) was about to start. Dr. Reuther added that they were looking at the material dynamics as well as fluid physics.

Chief Technologist Update

Dr. David Miller, NASA Chief Technologist, provided an update of the OCT activities. Among these is model-based systems engineering (MBSE), which is an active area at NASA, as well as in industry and the Department of Defense (DOD). It is a way to archive the design

process chronologically that enables analysis. Dr. Reuther added that it goes beyond design to manufacturing, and test and integration.

The Space Science and Technology Partnership Forum involves high-level coordination among the partnership members. It identifies hot topics and synergies, coordinated messages to Congress and the White House, and strategies for collaboration.

NASA is increasingly tying technologies to mission needs. It is not possible to support the entire range of projects from the roadmaps, so OCT looks at how to leverage and focus investments on a set of missions the Agency can support. Dr. Miller provided examples of this and risk reduction programs. Exploration involves resilience and logistical efficiency, which dictate the OCT emphasis on modularity, commonality, extensibility, and affordability. Architecture plays a key role in exploration and is the organizing theme, pulling together science, engineering, and technology.

Jason Kessler said that engaging a broad community through the Asteroid Grand Challenge Initiative could accelerate NASA's work in this area. This involves reaching out to people who do not normally attend NASA events. Engaging citizen scientists is difficult, but eight proposals came in, and OCT hopes to issue one or two awards to help amateurs help NASA. Another way of engaging citizens is through the Apophis 2029 mobile game, a partnership between NASA and Verizon. It is similar to a number of popular games but it lets players characterize real asteroids as they employ weapons to prevent asteroids from hitting Earth. NASA is hoping to enlist millions of people to choose the type of asteroid based on the graphics that are part of the game. Anyone with a mobile phone can play; it will be available in the fall.

Dr. Miller summarized his presentation by noting that the roadmaps have been expanded and released and providing technology transfer data. The NRC has begun ramping up for the next review, and the software catalogue has been released. Prizes, challenges, and crowdsourcing constitute a way to help solve problems. The Emerging Space Office is a new activity within OCT and will issue solicitations.

Working Lunch with STMD Space Technology Research Fellows at JPL

The NASA Space Technology Research Fellows from the Space Technology Research Grant program met with the Committee members informally.

Discussion and Recommendations

Dr. Ballhaus asked the Committee members to determine what statements they wanted to make and what findings and recommendations they wanted to send to the full NAC. He began by suggesting that they commend Mr. Jurczyk and his team for the TRL advancement work being done at the centers. That raised the issue of the big demonstrations, which STMD will not do unless there is a change in funding. He suggested that STMD might do more TRL maturation at lower levels so that these technologies can go forward when needed.

Mr. Johns asked how to convey the urgency argument on the demonstrations, stating that there is a disconnect between what people hear and what NASA wants to do. The appropriators point to a rising budget and ask why STMD cannot do things. Dr. Ballhaus said that TI&E can give Mr. Jurczyk advice without going to the NAC, whereas it would take a unanimous vote from the NAC to go to the Administrator. TI&E should emphasize the importance of balance, then sell technology demonstrations on their own merits. Dr. Reuther said that doing just the lower TRLs would harm space technology. Mr. Jurczyk added that the technology demonstrations help justify the early stage work.

Mr. Oschmann noted that the technology demonstrations elicit support from other mission directorates. Dr. Ballhaus said that if the most important things are done well, the Agency will trust STMD to run the rest of the program. He asked what might happen if STMD went to the Administrator, asked for the most important four projects, and ran them well. Mr. Jurczyk said that the eight areas for STMD investment could be winnowed down to three, four, or five for this purpose. That could be an effective strategy. However, the content needs to be more focused.

Dr. Ballhaus said that the NASA administrators used to be able to get their priorities funded. He thought that if the Administrator wanted more funding for STMD, he would be able to get it. Mr. Oschmann expressed skepticism and pointed out that the Administrator had his own top three priorities. However, TI&E might be able to help by giving him tools he could tailor to his audience. Mr. Eichhorst was perplexed as to how this happened, and suggested that STMD might not have the support the Committee thought it had. Taking in SBIR has backfired from a funding perspective. The message should be that the technology amount cannot be touched.

Dr. Ballhaus said that the NAC has not been fully supportive. It was suggested that STMD terminate the idea of going to Mars and get attention that way. Perhaps it should not be tied to STMD alone. Dr. Weber thought that including other mission directorates in the urgency argument might be effective. STMD supports their work, so they should support STMD's budget. She advised against STMD including the complete, summarized budget for the Directorate. The total budget does not look bad, but when the SBIR/STTR and civil servant costs are stripped out, the real situation becomes evident. That should be the default way of presenting the budget. She also advised titling slides by the point to be made, not the topic of the slide. An example would be "Discretionary Budget Eroding" instead of the current "President's Budget Request." Mr. Jurczyk agreed that the charts mask the challenge. His team was already working on it and would come back to TI&E with new ways of presenting the information. Dr. Weber said that as they worked, they should think about what needs to jump off the page at the reader. The team should not leave the conclusion to the audience but instead should hit them with that message.

Mr. Neyland observed that there was a strategy problem. What struck him was the lack of a unified front from NASA for technology development. He saw a tradeoff between the interests of the mission directorates and their lack of involvement. That goes up to the Administrator. If this is the issue, perhaps Mr. Jurczyk should address the unified front problem, not the budget. STMD needs the ability to execute. If the mission directorates want SEP, for example, they need to be the ones to say the funding cannot go away.

Dr. Ballhaus wondered where the Chief Technologist is in all this, given that he advises the Administrator. Dr. Reuther said that they had thought about that and whether the funds should move back to the mission directorates with STMD just managing it. The downside is that when the mission directorates might raid these funds when they need to solve a problem on their missions. In addition, a significant portion of STMD's portfolio is partnered, so the other mission directorates are involved. SMD pays for things that are managed in STMD, for example.

Adjournment for JPL Tour

The meeting was adjourned at 2 p.m.

APPENDIX A

Agenda

NAC Technology, Innovation, and Engineering Committee Meeting
July 27-28, 2015
NASA Jet Propulsion Laboratory
Bldg 180 Room 101

July 27, 2015 – FACA Open Meeting

12:00 p.m.	Welcome and Overview of Agenda/Logistics (FACA Session – public meeting) Mike Green, Executive Secretary
12:05 p.m.	Opening Remarks and Thoughts Dr. William Ballhaus, Chair
12:10 p.m.	Space Technology Mission Directorate Status and Update Mr. Stephen Jurczyk, Associate Administrator, STMD
12:55 p.m.	Adjourn meeting to move to joint meeting with HEO Committee Move to Bldg. 186.
1:00 p.m.	Call joint HEO and TI&E meeting to order
1:05 p.m.	Overview of Space Technology Mr. Stephen Jurczyk, Associate Administrator, STMD
2:00 p.m.	Evolvable Mars Strategy – HEO Tech Development Efforts Mr. Jason Crusan, Director, Advance Exploration Systems, HEO
3:00 p.m.	Break
3:15 p.m.	Hydrocarbon Engine Overview Mr. Bill Hill, Deputy Assoc. Administrator for Exploration Systems Development, HEO Mr. Jim Norman, Director, Launch Services, HEO
3:45 p.m.	NASA Launch Services Overview Mr. Jim Norman, Director, Launch Services, HEO
4:15 p.m.	Joint Committee Discussions and Recommendations
5:30 p.m.	Adjournment

July 28, 2015 – FACA Open Meeting – TI&E Committee

8:00 a.m.	Welcome and Overview of Agenda/Logistics (FACA Session – public meeting) Mike Green, Executive Secretary
8:05 a.m.	Opening Remarks and Thoughts Dr. William Ballhaus, Chair
8:15 a.m.	Welcoming Remarks Dr. Charles Elachi, Director, JPL
8:30 a.m.	Update: Impacts on Past Budget Reductions on STMD Technologies Dr. James Reuther, Deputy Assoc. Administrator for Programs, STMD
9:15 a.m.	Update on Deep Space Optical Communications Project Mr. Thomas Glavich, Project Manager, JPL
10:00 a.m.	Update on Deep Space Atomic Clock Project Mr. Allen Farrington, Project Manager, JPL Dr. Todd Ely, Principal Investigator, JPL
10:45 a.m.	Update on Low Density Supersonic Decelerator Project Dr. Mark Adler, Project Manager, JPL Dr. Ian Clark, Principal Investigator, JPL
11:30 a.m.	Chief Technologist Update Dr. David Miller, NASA Chief Technologist
12:15 p.m.	Working Lunch with STMD Space Technology Research Fellows at JPL
1:00 p.m.	Discussion and Recommendations
2:00 p.m.	Adjournment for JPL Tour

July 29, 2015 - Non -Public Session - Council and Committees: NAC Annual All-Hands Meeting

10:00 – 10:30 a.m.	Meet & Greet *(light refreshments)*
10:30 – 12:00 p.m.	NAC Annual All-Hands Meeting with NASA Administrator Bolden

APPENDIX B

Committee Membership

Dr. William Ballhaus, Chair
Mr. G. Michael Green, *Executive Secretary*
Mr. Gordon Eichhorst, Aperios Partners, LLC
Mr. Michael Johns, Southern Research Institute
Dr. Matt Mountain, Space Telescope Science Institute
Dr. Dava Newman, Massachusetts Institute of Technology
Mr. David Neyland
Mr. Jim Oschmann, Ball Aerospace
Dr. Mary Ellen Weber, Stellar Strategies, LLC

APPENDIX C

Meeting Attendees

Committee Attendees:
William Ballhaus, Jr., *Chair*
G. Michael Green, *Executive Secretary*
Gordon Eichhorst
Michael Johns
David Neyland
Jim Oschmann
Mary Ellen Weber

NASA Attendees:
Mark Adler
Katie Boggs
John Bolen
Ian Clark
Dan Coulter
Bob Cox
Tom Cwik
Anyah Dembling
Les Deutrich
Todd Ely
Allen Farrington
Dave Gallagher
Tom Glavich
Josh Holt
Stephen Jurczyk, *STMD Associate Administrator*
Brian Miurhead ?
Firouz Naderi
James Reuther
Andrew Shapiro

Other Attendees:
Amy Reis, Zantech
Elizabeth Sheley, Zantech
Steve Squyre, Cornel

APPENDIX D

Presentations

1) Space Technology Mission Directorate Update [Jurczyk]
2) Overview of Space Technology [Jurczyk]
3) Evolvable Mars Strategy – HEO Tech Development Efforts [Crusan]
4) Hydrocarbon Engine Overview [Hill, Norman]
5) NASA Launch Services Overview [Norman]
6) Update: Impacts of Past Budget Reductions on STMD Technologies [Reuther]
7) Update on Deep Space Optical Communications Project [Glavich]
8) Update on Deep Space Atomic Clock Project [Farrington, Ely]
9) Update on Low Density Supersonic Decelerator Project [Adler, Clark]
10) Chief Technologist Update [Miller]